

Patent Application of  
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for

## **TITLE: BENT-TUBE HEAT EXCHANGER**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

Continuation of prior Provisional Patent Application No. 60/409,423

### **BACKGROUND- FIELD OF INVENTION**

This invention relates to heat exchangers. The invented technology solves thermal expansion problem while reducing manufacturing costs and making the use of heat exchange surface more efficient.

### **STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT**

The invention was not made under a federally sponsored research and development.

### **BACKGROUND-DESCRIPTION OF PRIOR ART**

There are many types of heat exchangers. For heat transfer between two gases Baffled Shell-and-Tube heat exchangers are used most often. Baffled Shell-and-

Tube heat exchangers have, however, many disadvantages. One of the major disadvantages is inefficient use of heat exchange surface. Tubes near baffles are deprived from a sufficient outside gas flow and have very low heat transfer coefficient. Another disadvantage – because of temperature difference between the tubes and the enclosure, thermal expansion for straight tubes is different from the thermal expansion of the enclosure, making it impossible to create airtight connection.

## **SUMMARY**

The invention creates a new type of heat exchangers – Bent-Tube Heat Exchanger. It solves thermal expansion problem, allowing airtight welded connections for both sides of tube connection to tube sheets instead of a sliding connection on one side or use of expansion joints. Additionally, unlike in spiral-tube heat exchangers, the use of straight tube sections allows for uniform tube spacing and having the same length for all parallel tubes.

## **DRAWING FIGURES**

**Fig. 1** shows a typical Bent-Tube Heat Exchanger.

**Fig. 2** shows a typical arrangement for Bent-Tube Heat Exchanger with staggered tube banks.

**Fig.3** shows a configuration in which every second row is mirrored.

**Fig. 4** shows a typical arrangement for Bent-Tube Heat Exchanger in which tubes near sidewalls are bent with bigger radius.

**Fig. 5** shows an arrangement in which gas bypassing near sidewalls is decreased and thermal expansion related stress is minimized by bending tubing at 180 degrees.

**Fig. 6** shows typical arrangements for Bent-Tube Heat Exchanger shown on Fig.5 with staggered tube banks.

**Fig. 7** shows one an arrangement with two tube banks, which could be easily separated for cleaning or repair.

**Fig. 8** shows an arrangement in which there are several tubes bent together.

**Fig. 9** shows an arrangement with multiple parallel tube banks. Such an arrangement could be beneficial for high volume cross flow.

**Fig. 10** and **Fig. 11** show examples of possible arrangements for securing tubing in place.

For simplicity, all drawings show Bent-Tube Heat Exchanger without thermal insulation. While thermal insulation is required for most applications, its use is similar for all types of heat exchangers.

## **DETAILED DESCRIPTION OF THE INVENTION**

The description which follows, and the embodiments described therein, are provided by way of illustration of an example of a particular embodiment, or examples of particular embodiments, of the principles of the present invention. These examples are provided for the purposes of explanation, and not of limitation, of those principles and of the invention. In the description which follows, like parts are marked throughout the specification and the drawings with the same respective reference numerals. The drawings are not necessarily to scale and in some instances proportions may have been exaggerated in order more clearly to depict certain features of the invention.

**Fig. 1** shows a typical Bent-Tube Heat Exchanger. Unlike conventional heat exchanger with straight tubes and baffles to create a cross flow, the Bent-Tube

Heat Exchanger has bent tubes. It provides for two important benefits. First, it makes it possible to weld both ends of each tube to tube sheets **4**, located on **opposite** sides of heat exchanger. In conventional heat exchangers, because of thermal expansion, a sliding connection on one side is required. In the Bent-Tube Heat Exchanger, bent tubes are designed to absorb thermal expansion by bending without exceeding an allowable stress.

In the Bent-Tube Heat Exchanger, tubes could be bent at an angle, which provides for maximizing heat transfer rate and minimizing pressure drop. Baffles are not needed to achieve cross flow. Therefore, virtually all tube surface is participating in heat exchange. Side fins **5** or other form of flow restriction might be beneficial to compensate for lesser tube surface near walls, so that gas flow near walls will be heated (or cooled) to the same temperature as the rest of the flow. Side fins, however, don't need to be installed near tubes and they should not prevent gas flow near tube surface.

Shell side gas enters through shell side inlet **1** and exits through shell side outlet **2**. Straight sections **3A** on both ends of tubing **3** are used to allow for more equal gas distribution. Tube side gas enters through tube side inlet **6** and exits through shell side outlet **7**. It should be noticed that for different applications gas flow directions could be different. An inlet can become an outlet and, accordingly, an outlet can become an inlet. Flow directions are determined by a specific application.

Side view on **Fig. 1** shows Bent-Tube Heat Exchanger with all tubes bent similarly. Many different ways of bending tubes and arranging them are possible. It is beneficial, for example, to move each even row left or right at half distance between tubes, creating staggered tube banks for better heat transfer efficiency. Such an arrangement is shown on **Fig. 2**. Please note that for clarity only part of heat exchanger is shown. In addition, for clarity the second row is shown in hidden lines.

**Fig.3** shows a configuration with every even row mirrored. Please note that for clarity only part of heat exchanger is shown. In addition, for clarity even rows **8** are shown in hidden lines.

To decrease gas bypassing near sidewalls, tubes near sidewalls can be bent with a bigger radius. An example of such an arrangement is shown on **Fig. 4**. Even mirrored rows (like rows **8** shown on **Fig. 3**) and/or short fins (like fins **5** shown on Fig. 2) might be used.

Another way to decrease gas bypassing near sidewalls and minimize thermal expansion related stress is by bending tubing at 180 degrees. Such an arrangement is shown on **Fig. 5**. It is the most beneficial for heat exchangers having high-pressure gas or liquid on tube side and having gas with near atmospheric pressure on shell side. It is also useful for gas to gas heat exchangers with high temperature difference because thermal expansion related stress is minimal. Long tubes minimize welding. A relatively small number of tubes make it easier to weld tubes to drums **9** and **10**. In addition, tube-side headers or any other collection device could be used instead of drums.

Shell side gas enters through shell side inlet **1** and exits through shell side outlet **2**. Straight sections **3A** of tubing **3** at both ends are used to allow for more equal gas distribution. Tube side gas enters through tube side inlet **6** and exits through tube side outlet **7**. It should be noticed that for different applications gas flow directions could be different. An inlet can become an outlet and, accordingly, an outlet can become an inlet. Flow directions are determined by a specific application.

Many other combinations are possible. **Fig. 6** shows an arrangement in which every even tube is moved a half of distance between tube centers in a bend. It

results in creation of staggered tube banks, which have higher heat transfer coefficient for the same pressure drop. **Fig. 7** shows an arrangement similar to that on **Fig. 6** except that both inlet and outlet consist of two drums each. Odd tubes are connected to upper inlet **9A** and outlet **10A** drums, while even tubes are connected to lower inlet **9B** and outlet **10B** drums. Even tubes are welded to removable tube sheets **4A**, which are also covers. Odd tubes are welded to removable tube sheets **4B**, which are also covers. Therefore, heat exchanger consists of two separate tube bundles. Such an arrangement will allow removal of a combined bundle and separating it into two bundles. Because of much higher distance between tubes in each separate bundle than in the combined bundle, cleaning can be done much easier. For example, a rotating brush might be inserted between tubes after bundles are separated.

Tube sheets **4A** and **4B** do not have to be removable to separate tube bundles. A single flange **11**, located on the perimeter of heat exchanger can be used to separate both tube bundles. Upper part of the heat exchanger together with tube bundle of even tubes, tube sheets **4A** and drums **9A**, **10A** could be lifted, while lower part remains in place.

**Fig. 8** shows an arrangement in which several tubes are bent together. Such an arrangement could be beneficial for higher volume flow inside tubes.

**Fig. 9** shows another possible arrangement. Such an arrangement could be beneficial for high volume cross flow. Each tube row could be also a combination of any of the above arrangement.

Where are many ways to secure tubing in place. One of possible arrangements is shown on **Fig. 10**. Horizontal tube support bars **12** are welded to back wall of heat exchanger perpendicular to tubing plane. A row of tubing is hinged on these bars.

After that horizontal spacer bars **13** are welded to the horizontal tube support bars. Wideness of horizontal spacer bars is equal to distance between tube rows. These horizontal spacer bars do not allow horizontal movements of tube rows and preserve distance between them. A next row of tubing is hinged on these tube support bars on the other side of horizontal spacer bars and held in place by additional horizontal spacer bars welded to tube support bars on the other side of the row of tubing. It is repeated until all tubing is assembled. Such an arrangement has very low aerodynamic resistance while securely holding pipes in the place.

**Fig. 11** shows another possible arrangement. Rows of tubing are supported by a plate **14**, while horizontal bars **15** are maintaining a proper distance between tubes. While this arrangement can be used for both vertical and horizontal heat exchangers, in horizontal heat exchangers the weight of tubes is supported by plate **14**, while horizontal movement of tubes is not limited.

There are many possible applications for the Bent-Tube Heat Exchanger. One of possible application of Bent-Tube Heat Exchanger is in heat exchangers used for gas turbines. Hot low-pressure gas from turbine exhaust is used to preheat cold high-pressure air entering turbine combustion chamber. Because of high pressure at tube side, drums can be used as high-pressure air inlet and outlet. Tubing could be bent and welded to the drum. Similar drum connections are often used in industrial steam boilers.

Another possible application is for cryogenic-service heat exchangers. Currently used spiral-tube heat exchangers have difficulties in making tube spacing uniform to prevent channeling of low-pressure gas. In addition, because each spiral has its own radius, lengths of various parallel tubes are different. The Bent-Tube Heat

Exchanger has both uniform tube spacing and the same length for all parallel tubes.

The above description is only an example of a possible equipment arrangement. Many other arrangements are possible. For example, bent tubes could be installed inside a cylindrical reactor; tubes themselves are not necessary bent in one plane. Bonnets can be used for tube-side flow. In another example, heat exchanger may consist of cylindrical body and spiral tubing inside it. Spirals could have different radii with each spiral located within a bigger spiral, or they might have the same radius and be located side by side, penetrating each other or not. Any combination of spirals of different diameters and lengths could be used.

### **Conclusions, Ramifications, and Scope of Invention**

The invented Bent-Tube Heat Exchanger provides a new type of heat exchangers. Unlike conventional Baffled Shell-and-Tube heat exchangers, in which baffles are used to create cross flow, in the Bent-Tube Heat Exchanger cross flow is created by changing directions of tubes and locating them across the flow.

While my above description contain many specificities, these should not be construed as limitations on the scope of the invention, but rather as an exemplification of one preferred embodiment thereof. Many other variations are possible.

Accordingly, the scope of the invention should be determined not by the embodiment(s) illustrated, but by the appended claims and their legal equivalent.